

Soil in millipede diet: implications on faecal pellet stability and nutrient release

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Summary. A laboratory experiment using *Alloporus uncinatus* faecal pellets was performed to determine the effect of mineral soil in millipede diet on the stability of faecal pellets in distilled water. Pellets were generated using three food types, mineral soil, ground *Cupressus* sp. litter and a 1 : 1 by volume mixture of ashed soil with ground *Cupressus* sp. litter. Field pellets were generated from freshly collected individuals. The crumbling time of each pellet (for each food type) after putting them singly in distilled water (5 ml) was recorded. Pellets generated from food ingested in the field (field pellets) retained their cylindrical shape for much longer (\bar{x} = 240 minutes) than the other types of pellets. Field pellets contained 52 percent mineral particles compared to 65 percent in laboratory pellets generated from the soil-litter mixture. The pellets generated from the mixture, however, remained stable for much longer (\bar{x} = 213 minutes) than those from ashed soil (\bar{x} = 28 minutes) and leaf litter (\bar{x} = 33 minutes). The evolution and implications of stable pellets in natural environments were considered.

Key words: *Alloporus uncinatus*, faecal pellets, *Cupressus* sp. litter, mineral soil

Introduction

According to Dangerfield & Telford (unpublished) savanna millipedes produce 30 to 60 g per square metre of faecal pellets annually. The faeces of soil invertebrates are composed of undigested plant material, soil organisms, fine organic matter and mineral particles (Tajovsky *et al.* 1992). Although plant material remains the major food source (Wooten & Crawford, 1975) upon which millipedes subsist, millipedes have a wide dietary range which includes soil (Dangerfield 1993).

Outside the millipede body the proportion of mineral particles as a constituent of faecal pellets may influence the persistence of pellets. Tajovsky *et al.* (1992) reported that in calcareous soil faecal pellets of millipedes remain stable for a long time may be because of the high content of calcium in the soil. Dangerfield & Milner (unpublished) also reported long periods of millipede faecal pellets persistence if mineral particles are ingested. It is, however, not clear whether soil ingestion by millipedes is accidental or that soil is required as roughage and reduce passage time of ingested material or provide nutrients especially salts required in the production of the exoskeleton (Dangerfield 1993).

Faecal pellets of tropical millipedes are cylindrical. Individual mass of pellets varies from 8.0 to 85.0 mg depending on species, sex and body mass (Dangerfield & Telford, unpublished). The mean pellet length and width of 10 g individuals of *Alloporus uncinatus* (Attems, 1928) is 0.6 and 0.3 cm, respectively (Mwabvu, In prep.).

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Materials and Methods

Pellets were generated from millipedes collected from a *Cupressus* sp. plantation growing in granite derived soils in Harare, Zimbabwe (17°30' S, 30°57' E). Large populations of *Alloporus uncinatus* occur during the summer rainfall season which begins in November and ends in April. Collection of millipedes, *Cupressus* sp. litter and soil was by hand.

Collected millipedes weighing between 9 and 10 grams put in glass tanks (length 75 cm, width 35 cm, depth 20 cm). The pellets that were produced were collected after 24 hours and dried at 60 °C for 24 hours. Millipedes that had been collected from the same site three weeks earlier and stored without food were used to generate pellets using food prepared in the laboratory. Pellets that were produced during this starvation period were discarded. After the three week starvation period (meant to clear the gut) the animals were randomly allocated to three food types, ashed soil, ground *Cupressus* sp. litter and a 1:1 by volume mixture of *Cupressus* sp. litter with ashed soil. Soil was ashed at 650 °C for 24 hours in a muffle furnace. Pellets produced from each food type were collected and dried as above. All pellets were collected at the same time.

The dried soil pellets, litter pellets, soil-litter pellets and field pellets were each dropped into a vial (4 cm diameter) containing 5 ml of distilled water and the time taken for each pellet to crumble recorded. Crumbling time of a pellet in distilled water was recorded as the time taken for the cylindrical shape to be lost after immersion.

Some field pellets were dried at 60 °C, weighed and ashed at 650 °C for 24 hours in a muffle furnace to determine the proportion of organic matter and mineral particles in the pellets.

Results

Field pellets were darker in colour than those generated from animals fed on laboratory prepared food. The mean crumbling time of field pellets ($n = 122$) was 240 minutes compared to 28 minutes for soil pellets ($n = 169$), 213 minutes for pellets from *Cupressus* sp. litter with soil mixture ($n = 112$) and 33 minutes for *Cupressus* sp. litter pellets ($n = 63$). There were significant differences between the soil pellets and field pellets ($p = 0.000$), soil pellets and soil-litter pellets ($p = 0.000$) and between the field pellets and the soil-litter pellets ($p = 0.019$). There was no significant difference between the crumbling time of soil pellets and *Cupressus* sp. litter pellets ($p > 0.05$).

Field pellets contained 52 percent mineral particles compared to 65 percent in pellets generated from food that was prepared in the laboratory.

Discussion

The proportion of mineral particles in faecal pellets has significant effects on faecal pellet stability. Field pellets were more stable in distilled water; they contained 52 percent mineral particles and 48 percent organic matter. Pellets generated in the laboratory, after millipedes fed on a *Cupressus* sp. litter-soil mixture contained 65 percent soil and 35 percent organic matter. Pellets generated from ground litter only and mineral particles only did not show any difference in stability ($p > 0.05$). The results suggest that mineral particles in millipede diet confer stability on the faecal pellets. However, the results do not show the proportion of mineral particles that would give maximum stability. A millipede fed on mineral soil only or leaf litter only produces pellets that are fragile and unstable. Although mineral particles give pellets stability, the results suggest that pellet stability would decrease as the proportion of mineral particles increase to unity. Tajovsky *et al.* (1992) reported that a high content of calcium is thought to be the cause of pellets stability in calcareous soil. However, the element that causes stability in tropical millipede pellets is not known. If coprophagy is an important feeding tactic in millipedes, selection pressure would favour individuals that produce stable pellets.

This seemingly trivial point lends support to the "external rumen" theory (Hassall & Rush-ton 1985). The longer the pellets maintain their shape the more time micro-organisms have

to break down egested undigested organic matter before reingestion. Kheirallah (1979) and Dangerfield (1993) reported that millipedes show food selection. Mineral soil may therefore not be ingested by accident. Individual millipedes that make the best choice would be favoured by selection forces because of their ability to get the most out of the ingested or re-ingest food items.

Pellets may also become a store of nutrients where decomposition is not limited by moisture availability (Dangerfield & Milner, unpublished). This is of particular importance considering that soil invertebrates return between 60 and 90 percent of ingested litter to soil as faecal pellets (Tajovsky *et al.* 1992). According to Dangerfield & Milner (unpublished) millipedes may be an important factor in the evolved synchrony between nutrient release and uptake in natural systems. The stability of pellets may therefore have a direct influence on the rate of nutrient release.

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